Total Dose Survivability of Hubble Electronic Components

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Acronyms

- AE-8 – Aerospace Electron Model-8
- AP-9 – Aerospace Proton Model-9
- CEASE – Compact Environmental Anomaly Sensor
- CMOS – Complementary Metal-Oxide-Semiconductor
- HST – Hubble SpaceTelescope
- IR - infrared
- JWST – James Webb Space Telescope
- NOVICE – Numerical Optimizations, Visualizations, and Integrations on CAD/CSG Edifices
- CAD – Computer Aided Design
- CSG – Constructive Solid Geometry
- PET – Proton Electron Telescope
- RAM – Random Access Memory
- ROM – Read Only Memory
- RPS – Relativistic Proton Spectrometer
- SAMPEX – Solar Anomalous and Magnetospheric Particle Explorer
- TID – Total Ionizing Dose
- TSX-5 – Tri-Service Experiments Mission 5
- 3-D – three-dimensional

Outline

- Introduction
- HST Lifetime Planning
- Total Dose Analysis and Results
- Summary

Credit: http://www.spacetelescope.org

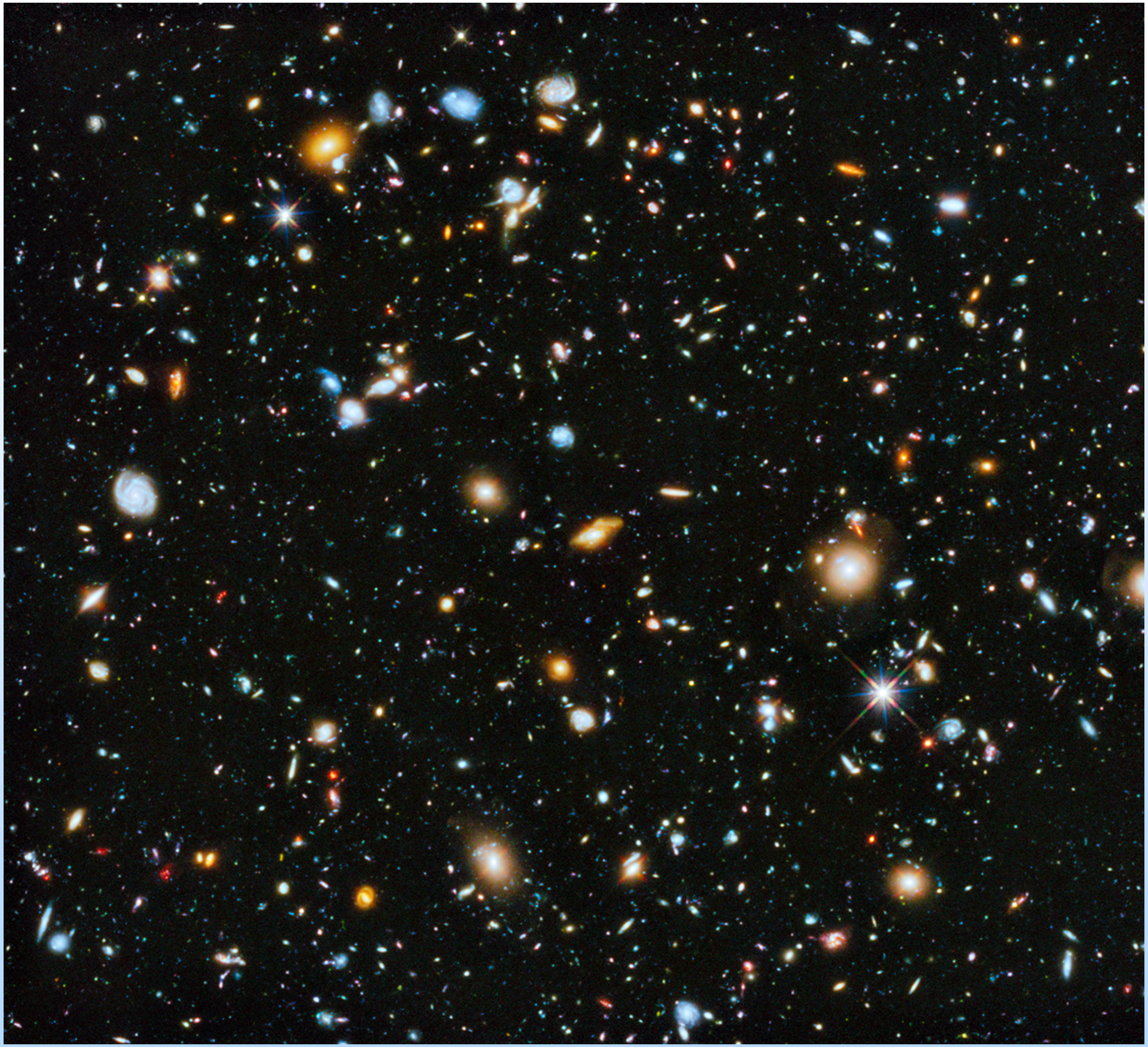
Introduction

- **Hubble Space Telescope (HST) deployed from Discovery April 25, 1990**
  - **Low Earth Orbit, 569 km altitude, 28.5^{o} inclination**
  - **First telescope designed to be serviced in space**
- **Advantages in space:**
  - **No atmospheric distortions**
  - **Little background light**
  - **Portions of ultraviolet and infrared spectra seen, not observable with Earth-based telescopes**

2.4 meter diameter primary mirror

Credit: http://hubblesite.org/

The Universe, Looking Back in Time



Credit: http://hubblesite.org/

Service Mission 1
Corrective Optics for Spherical Aberration

Galaxy M100, Before

Galaxy M100, After

Credit: http://hubblesite.org/

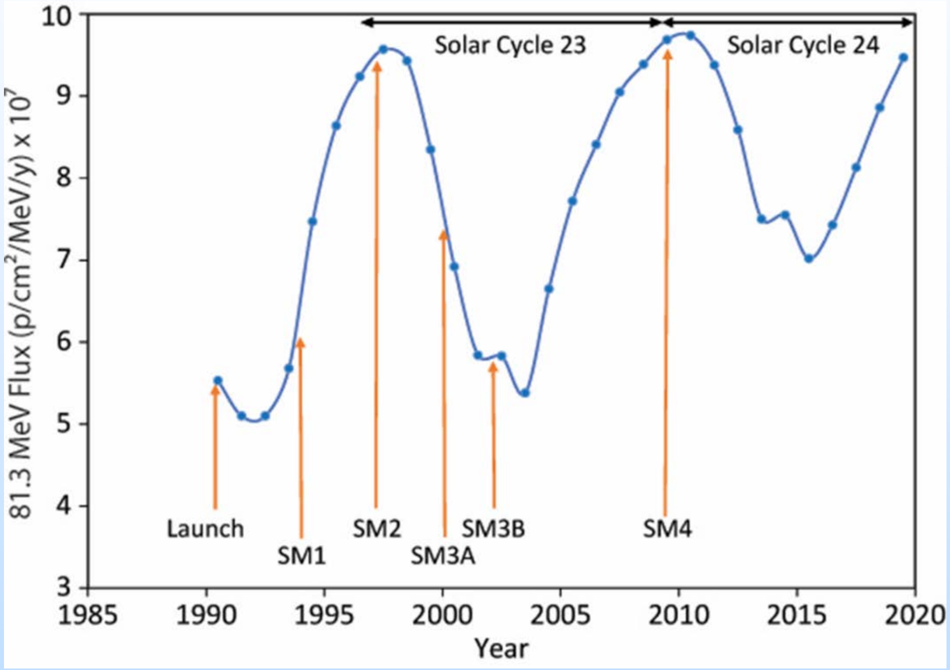
HST Lifetime Planning

- Fifth and final HST servicing mission occurred in May 2009
- James Webb Space Telescope (JWST), launches in October 2018
  - Will complement and extend HST discoveries with greater IR wavelength coverage and sensitivity
  - Desirable that HST and JWST operate simultaneously
- After more than 27 years in orbit, main radiation concern for HST is a hard failure due to total ionizing or non-ionizing dose.
  - Objective is to evaluate these possibilities out to the year 2020 for HST life extension initiatives and contingency planning

Total Dose Analysis
Van Allen Belts

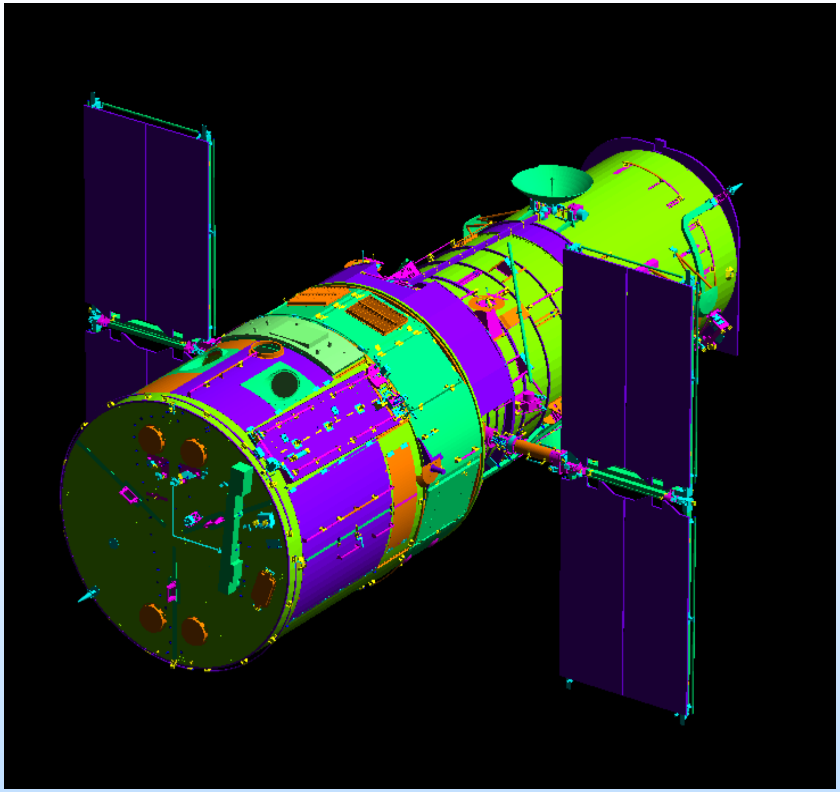
- **Dose comes mainly from trapped p, with smaller contribution from trapped e**
- **Must account for solar cycle dependence of fluxes**
- **Boeing Trapped Proton Model-1 used**
  - **AP9 used to extend energy range to 2 GeV (RPS instrument on Van Allen Probes)**
  - **Calculations showed good agreement with SAMPEX PET and TSX-5 CEASE data**
- **AE8 used for trapped electrons**
  - **Results insensitive to electron model**

Boeing Trapped Proton Model-1
HST Orbit



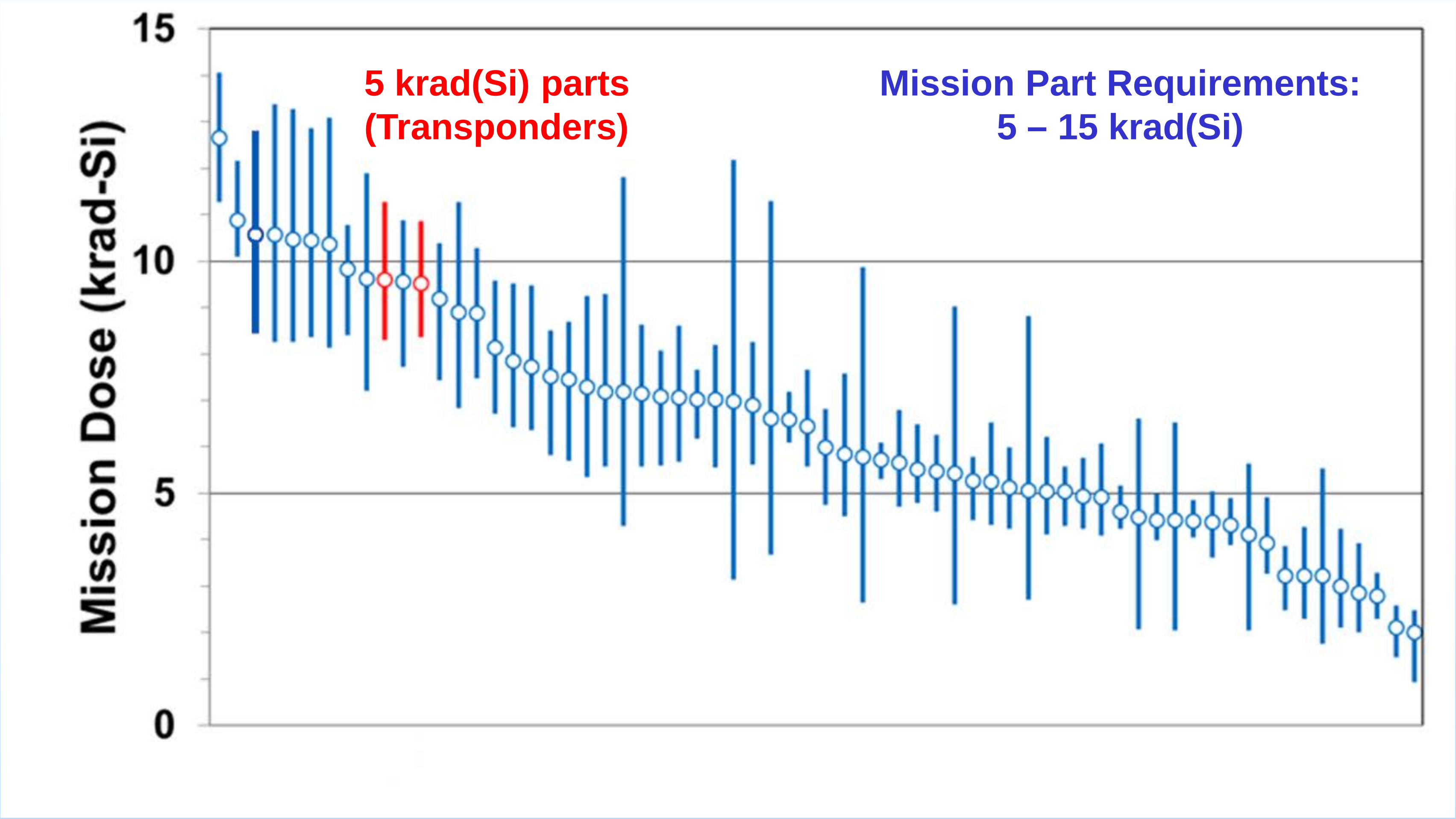
Total Dose Analysis
Radiation Transport

- **NOVICE code used for radiation transport**
  - **Interfaces with CAD models**
  - **Adjoint (reverse) Monte Carlo simulation greatly increases calculation efficiency**
- **Lockheed Martin spacecraft CAD model imported**
- **Extensive review of subsystem and instrument mechanical drawings**
  - **Implemented using correct dimensions, wall thicknesses, masses and placement**
- **TID exposure tracked accounting for servicing missions**



HST NOVICE Radiation Model

Expected Mission Doses by 2020
66 Subsystems / Instruments



Parts Discussion

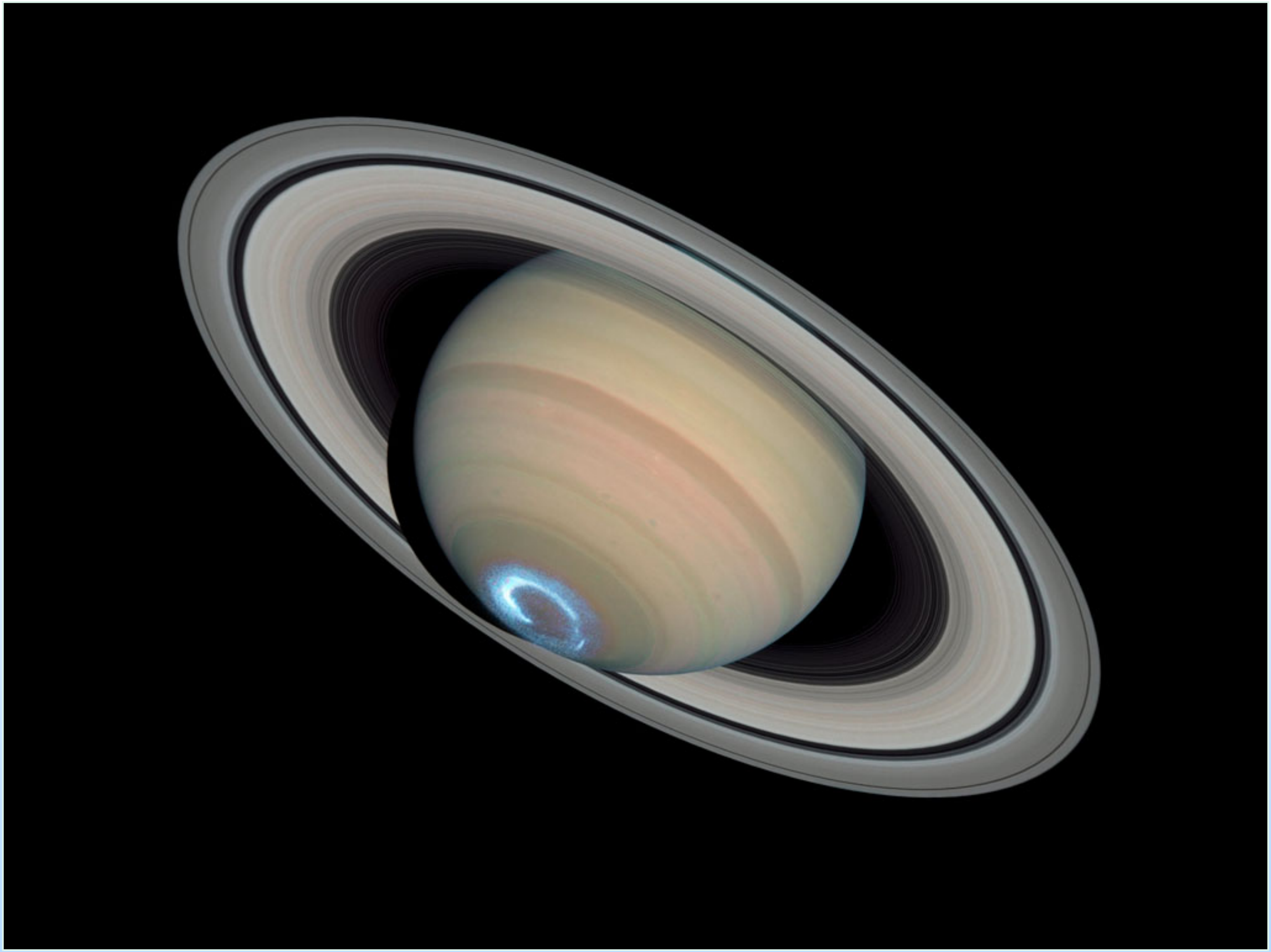
- **HST Parts and Control Plan specifies TID hardness of 5 - 15 krad(Si)**
  - **Many selected parts substantially exceed this**
- **Initial HST development occurred in 1980s**
  - **Bipolar technologies generally more total dose hard than CMOS**
  - **Literature and parts list reviews showed total dose concerns were primarily CMOS parts**
  - **Biggest concern is Hughes Aircraft CMOS parts in transponders - microprocessors, RAM and ROM**
    - **Will be exposed to ~2X their total dose hardness by 2020**
- **Factors favoring part survivability:**
  - **Annealing of parts for many years in space not accurately accounted for with ground test protocol**
  - **Parts may operate satisfactorily outside specs**

Summary

- HST has been through:
  - 27 years of mission operations
  - 5 servicing missions
  - 3 generations of scientific instruments
  - 14,000 electronic parts
    - Procured by 5 generations of parts engineers
    - Protected by 12,200 kg of spacecraft mass / shielding
- HST still operating satisfactorily

To Be Continued…..

Questions?



Credit: http://hubblesite.org/

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